INVESTIGATING THE WIDTH OF COSMIC-PARTICLE SHOWERS AT SEA-LEVEL

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Results of investigations of the width of atmospheric showers, undertaken in 1938 by Auger (1), indicated that experimental data diverges from computations performed on the basis of the cascade theory (2). The dependence, on mutual distance, of the number of discharge coincidences in two counters apparently was in satisfactory agreement with theory for distances less than 100 - 150 m, while at distances of 300 m the number of coincidences exceeded the expected value. However, insufficiently accurate computations for large distances and the limited statistical material did not allow one to draw any conclusions as to the existence of anomalous shower-widths. Moreover, computations performed by Moliere (3) led him to conclude that Auger's experimental data agrees satisfactorily with predictions of the burst theory.

The method applied by Auger did not allow one to reach large distances, because of the conspicuous background of accidental coincidences.

In 1946 G. T. Zatsepin and V. V. Miller (4) succeeded, by employing another method of shower recording, in reaching distances of 980 m and established the existence of a sharp disparity with theoretical predictions. As was further shown by D. V. Skobeltsyn (5,6), the number of coincidences at 1-km distance exceeds by a factor of tens the magnitude obtained as a result of successive application of the avalanche theory.

A number of works (4.7,8) also indicated the anomalously wide divergence also of high-energy electrons ("trunk" of the avalanche). The assumption of the existence of a nuclear-cascade process and of its decisive role in the development of broad showers (9) explains qualitatively the possible reasons for the disparity between avalanche theory and experiments. However, the participation of little-known nuclear processes in the formation and passage of wide showers through the atmosphere strongly confuses the shower picture and sometimes deprives us of the possibility of a simple analysis of experimental results. In this respect the study of the properties of wide showers at low altitudes, nearly at sea-level, acquires particular interest. The advantages of shower investigations at sea-level are the following:

1. Because of considerable filtration by the atmosphere, the initial average energy of recorded showers at sea-level is considerably greater than on high mountains and their content of the penetrating component is apparently much greater.

2. The different absorption-character of soft and penetrating particles (e.g. μ-mesons) may lead to the possibility of spatial separation of the various components of showers (according to altitude, and also according to a given depth in the atmosphere). In this case analysis of the properties of showers' electron-photon part will allow one to judge the reliability of the data on cascade theory used for the explanation of atmospheric showers.

Studies of the properties of the penetrating component may shed some light on the mechanism of nuclear processes at super-high energies of particle interaction.

We investigated the width of atmospheric showers at sea-level by the method of multiple coincidences suggested by D. V. Skobeltsyn and formerly employed by G. T. Zatsepin and V. V. Miller during measurements on the Pamir (3860 m above sea-level). The scheme of equipment is shown in figure 1, where 1,2,3,4 are groups of counters (each group consists of 12 fast-operating counters connected in parallel and located close to each other; the total area of counters of each group was 3960 cm^2). Amplifiers S_1 and S_2 detected double coincidences 1-2 and 3-4. Amplifier S recorded the coincidences of pulses, passing from S_1 to S_2 along the high-frequency cable. The number of quadruple coincidences (C_4) relative to distance D between equipment I and II was measured. The resolving power of the amplifier corresponded to $\tau = 4.10^{-6}$ sec, which enabled us to neglect accidental coincidences. The equipment was located in light wooden housings.

As known from the avalanche theory, the width of a shower is determined by the deviation of low-energy particles scattered through sufficient angles. Because of this circumstance "the mean square radius at sea level is about 70 m (10) and should increase with altitude in correspondence with variations in air density and corresponding variations in t-unit length. At altitudes of 3860 m we have $R \approx 100$ m approximately.

At great distances from the shower's axis a considerable fraction of the electrons is produced by the conversion of low-energy photons of the corresponding region of minimum coefficient of photon absorption.

Figure 2 represents (in a logarithmic scale) the dependence C_4 (D) obtained by G. T. Zatsepin and V. V. Miller on the Pamir (curve I). If we assume that in their work the main part of coincidences close to the greatest distances was produced by avalanche electrons, we should expect that the shape of the curve $C_4(D)$ for other altitudes could be obtained from the derived dependence by a change of scale on the abscissae axis according to variations in the t-unit. The curve transformed in such a way for sea-level is represented in figure 2, II. In table 1, we assembled results of measurement performed at sea-level during 1949 - 1950. In figure 2 the corresponding values are designated by verticle dashes. As seen in the figure, for small distances (D 50 m) experimental points really overlap curve-II*, thus confirming that at these distances coincidences are produced by particles of electron-photon avalanche possessing a sharply defined "diameter" **. However, at large distances experimental points pass from curve-II to non-deformed curve-I.

NOTE: According to the avalanche theory, at distances small in comparison with shower radius, the law of spatial divergence of particles varies with atmospheric depth according to the expression: $\rho(r) \approx 1/r^{2-s}$ (14). This variation should affect the shape of the "expansion curve" at small distances. Actually, at D = 12 m Kraybill (15) observed the difference in the number of coincidences of about 5 - 10% in the case of a variation observation post from 720 to 9200 m above sea-level. It is natural that in our altitude interval this difference is still less important. In addition there is some indetermination in the value of $C_4(D)$ at D = 1 - 2 m (effect of narrow showers from the roof or from the air). In order to detect the difference in the shape of "expansion curves" at small distances, more accurate measurements are required. The conformation of "expansion curves" at sea-level and on the Pamir has been done for distances D = 5 - 10 m. Investigations of shower widths at sea-level were first performed; thereafter for comparison with data of altitude measurements, only the results of the authors were used.)

**(NOTE: Questions of the exact meaning of "diameter" of showers and agreement of this value with predictions of the cascade theory are not discussed in this article.)

Within the limits of accuracy of present measurements, the shape of the "expansion curve" at great distances (up to 400 m) does not differ from the shape of the corresponding curve for the 3860-m altitude; that is, the function $C_4(D)$ may be expressed in the form: $C_4\ (D) \approx 1/D^k$, where $k = 2.6 \pm 0.15$. This confirms once more that atmospheric showers posses an anomalous width.

Various explanations of the anomalous width of showers are possible. The most natural ones are the following assumptions:

a) The avalanche particles (electrons and photons) may appear in considerable numbers at much greater distances than apparent in the modern cascade theory, because of imperfections in the latter and because of the presence of some additional unaccounted for mechanisms of particle dispersion.

b) The L. C. Cascade theory is correct and described in the right way the behavior of avalanche particles. Nevertheless the main part of particles at large distances from the shower's axis consists of electrons which got on the periphery by interference of nuclear processes in the development of wide showers (e.g. Electrons may be transported by heavy nuclear-active particles (11), produced as result of a nuclear cascade process (9); the possible existence of several trunks in showers is not excluded either (12,13)).

c) The expansion of avalanche particles is determined by the cascade theory. Beyond the shower radius at great distances from its axis the main part of particles are of other nature and origin (e.g. mesons and electrons in equilibrium with them).

The above-described experiments prove that at great distances coincidences are produced not by short-path particles coming from the trunk of the electron-photon avalanche, but by particles transported to the shower's periphery by another mechanism. We assume that wide showers consist of two parts:

1) electron-photon avalanche, developed according to the laws of the classical cascade theory, and

2) wide periphery, produced by particles of other origin (see b) or c)). Assumption a) apparently does not correspond to reality and the experimental "expansion curves" could be explained without admission of inacceptibility of the cascade theory for the explanation of electron-photon avalanches and the presence of some deviations in the law of scattering of soft particles.***

***(NOTE: In G. T. Zatsepin's opinion, the conclusion concerning the anomalous width of shower "trunks", based on the results of certain works (7,8), is not sufficiently founded, because the authors did not take into account a number of effects, in particular the fluctuation in passage of the electron avalanche through lead, and the possibility of getting of mesons in one of the shielded counters.)

Further investigations are necessary to explain the origin of particles on the periphery of showers. It is most natural to assume that at low altitudes the periphery of showers consists mostly of -mesons and particles in equilibrium with them.

In conclusion the author expresses his indebtedness to academician D. V. Skobeltsyn, and also to N. A. Dobrotin and G. T. Zatsepin, for their helpful discussion of results.

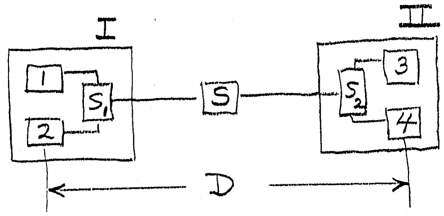

Figure 1.

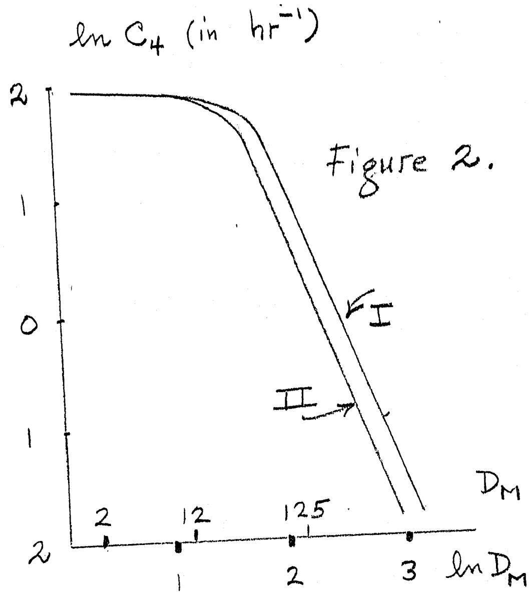

Figure 2.

TABLE 1.

D (meters)	2	12	21	33	53	98	112	125	400
Total No. of Coincidences C_4	758	393	315	535	337	154	317	186	39
C_4 Coin/hr	92.5 ± 3.3	75 ± 3.8	53.5 ± 3	37.4 ± 1.6	24.6 ± 1.4	12.4 ± 1.0	8.65 ± 0.5	7.45 ± 0.5	0.34 ± 0.06

BIBLIOGRAPHY

1 P. R. Auger, T. Mazeet, and Grivet-Meyer. CR 206, 1721 (1938).

2 D. V. Skobeltsyn. DAN 37, 16 (1942).

3 G. Moliere. Kosmische Strahlung, Berlin: 1943, p 24.

4 G. T. Zatsepin and V. V. Miller. ZhETF 17, p 939 (1947).

5 D. V. Skobeltsyn. G. T. Zatsepin and V. V. Miller. Phys Rev 71, p 315 (1947).

6 D. V. Skobeltsyn. DAN 67, p 45 (1949).

7 D. M. Alekseyev. G. T. Zatsepin and I. G. Morozov. DAN 63, p 375 (1948).

8 G. T. Zatsepin. S. A. Kuchay and I. L. Rozental. DAN 61, p 47 (1948).

9 G. T. Zatsepin. DAN 67, p 993 (1949).

10 S. Z. Belen'kiy. "Avalanche Processes in Cosmic Rays" 1948.

11 G. T. Zatsepin and L. I. Sarycheva. DAN 69, p 635 (1949).

12 D. V. Skobeltsyn. DAN 67, p 255 (1949).

13 D. V. Skobeltsyn and G. T. Zatsepin. DAN 73, No 6 (1950).

14 A. Migdal. ZhETF 15, p 313 (1945).

15 H. L. Kraybill. Phys Rev 76, p 1092 (1949).

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